Forest Fire Vulnerability analysis in India-A Case Study of Uttarakhand State

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ABSTRACT

India has 78.37 million hectare forest and tree cover which is 23.84% of the geographical area of the country (India State of Forest Report, 2009). The vulnerability of forest type, with respect to forest fire is an outcome of the variability and frequency of the fires. The incidences of forest fire influences soil carbon which may cause modification in the structure of forest type. Forest fire susceptibility and risk mapping using remote sensing and geographical information systems (GIS) can be an important tool to take immediate measures in near real time by the Provincial/State Forest Departments in an automated manner and can help in retaining the structure of forest type in cost effective manner, besides reducing the incidences of forest fire. The paper presents innovative 'vulnerability analysis' using spatial databases for Uttarakhand in India.

Key words: Vulnerability, Forest Type, Forest fire susceptibility, risk mapping.

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INTRODUCTION

The present study is focused on forest fire vulnerability in Uttarakhand, India. Forest landscapes across the State of Uttarakhand faces on an average 400 incidences of forest fire every year. As such insufficient information and knowledge on fire vulnerable regions could make management imperatives more difficult in these areas. The frequency of forest fires may lead to deferment of a comprehensive mitigation and adaptation framework. Hence it is important to optimize the use of available resources and undertake vulnerability assessment to primarily aid the creation of an efficient plan for taking effective steps to control forest fire incidences. The forest fire pattern changes the structure of forest type finally modifying the species and the forest type of the region. The monitoring and adaptability of climate change is very important as it may change the forest fire pattern. Forest fire events for the past 7 years for the study area has been analyzed using topography, climate, fuel load and agro climatic conditions using spatial databases to determine location specific Forest Fire Vulnerability for Uttarakhand State of India.

The scientific literature has been able to isolate both biophysical and anthropogenic variables which both enhance and decrease forest fire vulnerability, such as temperature, precipitation, topography, vegetation type and density, soil moisture and human presence. However, the integration of these many variables into a single model is not always simple (Arienti et al., 2006; Cyr et al., 2007; Gonzalez et al., 2007; Lavorel et al., 2007; Podur et al., 2002; Wotton and Martell, 2005). Problems arise when available data is partially

available and may not be efficient in addressing the issue of vulnerability. To accurately determine fire vulnerability models one would require a combination of multi-scale and interdisciplinary regional data (Lavorel et al., 2007).

The present study analysed the frequency of occurrence of fire depends on many spatial parameters such as fuel type, fuel load, temperature, topographic and moisture conditions and the biotic influence in the area. It is also dependent on non-spatial parameters such as population density, socio-economic conditions prevailing in the area and other such parameters. On the basis of available GIS based forest fire information and superimposition of attributes of physiographic data, risk zonation of forest fire can be carried out to determine forest fire behavior, modeling can lead to generating vulnerability indices.

Based on the review of the past studies on forest fires, very few studies have been observed to be carried in the field of fire vulnerability. Though different approaches for assessment of fire vulnerability have been used, no such study has been reported to be using the data on fire occurrences in a region. This may be attributed firstly to non-availability of continuous and periodic fire records and second to the occurrence of the spatial information for the fire incidences as point attribute.

Study Area

Uttarakhand is situated between 28°43' N - 31°28' N latitude and 77°34' E - 81°03' E longitude in northern Himalayan region of the country. Geographical area of the state is 53,483 km^2 which constitute 1.63% of the country's total area. State has total 13 Districts. Physiographically, the state can be divided in to three zones namely, the Himalayas, the Shiwaliks and the Tarrai region. The state has a temperate climate except in the plain areas where the climate is tropical with temperatures ranging from sub-zero to 43oC. The average annual rainfall is 1550mm. Based on ISFR 2011 forest cover of the state is 24496 km^2 which is 45.80% of the geographical area of the state. In terms of forest canopy density classes, the state has 4762 km^2 area under very dense forest, 14167 km^2 area under moderately dense forest and 5567 km^2 area under open forest.

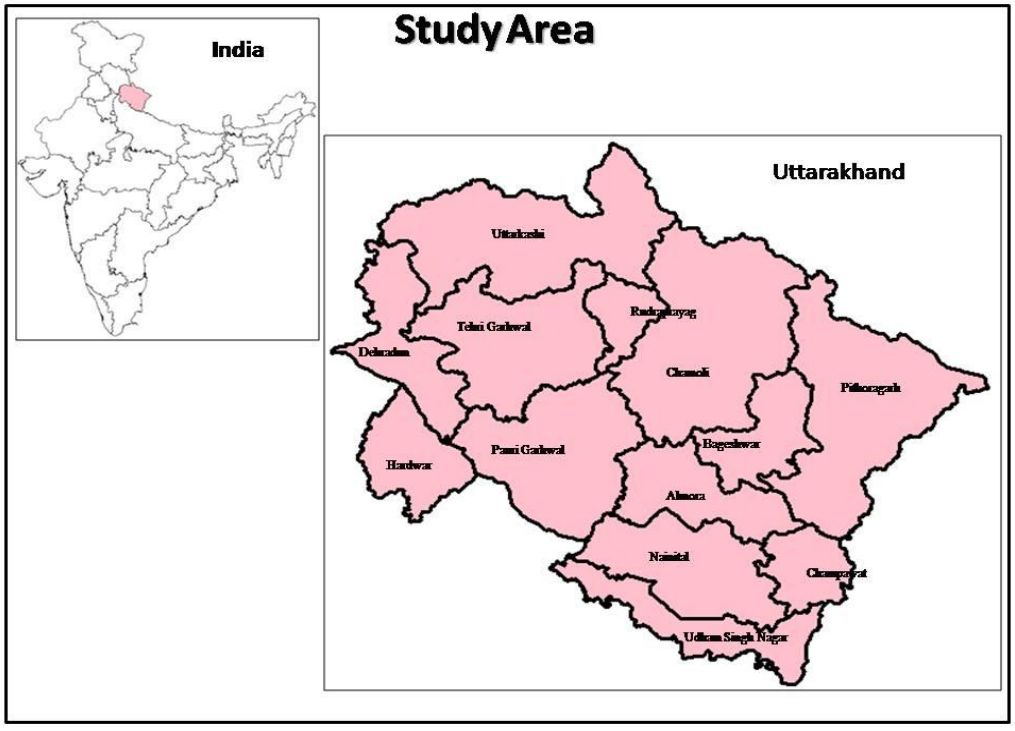

Figure 1. Map Showing the Study area Uttarakhand

MATERIALS AND METHODS

Vulnerability analysis primarily entails information on regimes and forest strata that face frequent occurrence of forest fires due to various reasons. Remote sensing and GIS plays an important role not only in detecting the active forest fire locations, but also helps in assessment of the fire risk based on several factors such as topography, climate and other biological factors. There are several methods of mapping vulnerable areas and assessment of vulnerability indices. In the present study, vulnerability analysis has been carried out using the existing data for forest fire outbreaks over a period of seven years and analysis performed. Forest fire signals from the MODIS (Moderate Density Imaging Spectro-radiometer) sensor on board Terra and Aqua satellites have been used for identification of forest fire pixels. The vulnerability map has been prepared based on the time series data of the forest fires between 2004-2011.

The study utilized past forest fire data for assessment of vulnerable areas based on the frequency of occurrences of fires over a specific region. The information of the forest fire incidences occurred as point data. Each of the forest fire location, attributes such as state name, district name, toposheets number, date of fire incidence, and the geographical location of the fire incidences have been attached. As such, each of the fire location occurring in a GIS compatible format (point coverage/Shape file) entails complete information for further analysis. Accordingly, buffers were created around each cluster of fire-points to extrapolate the fire area of influence in the vicinity of core area. Point information has been used in the overlay analysis and buffer has been used to find the vulnerable areas. The buffers have been intersected with the buffers around forest fire spots recorded for the years 2004 to 2011 so as to identify the size of areas potentially vulnerable to forest fires. Areas common in continuous three year period has been termed as low vulnerable area, where as occurrence of fires for 4-6 years has been classified as moderately vulnerable area. In regions where incidences have been reported in all the seven years have been classed as highly fire vulnerable areas.

All the available information on forest fires in the study areas of Uttarakhand has been compiled for the respective years. The main data available were forest fire incidences (from 2004 to 2011), SOI Toposheet, Forest Cover Map, Forest Type Map.

Once the database (layers and attribute data) is assembled, the layers have been analyzed and new information extracted. Some information can be extracted simply by looking at the layers and visually comparing them to other layers. However, new information can be retrieved by combining and comparing layers using overlay analysis. In this exercise overlay analysis has been done with the forest fire point coverage and the forest cover map, forest type map, toposheets as well as 2.5'x2.5' grid of the state. whereas buffer around the cluster of the forest fire points has been related with the district boundary, poverty, literacy rate as well as rainfall data to find the relationship between forest fire vulnerability and these parameters. Figure 3 shows the methodology for the identification of the vulnerable areas

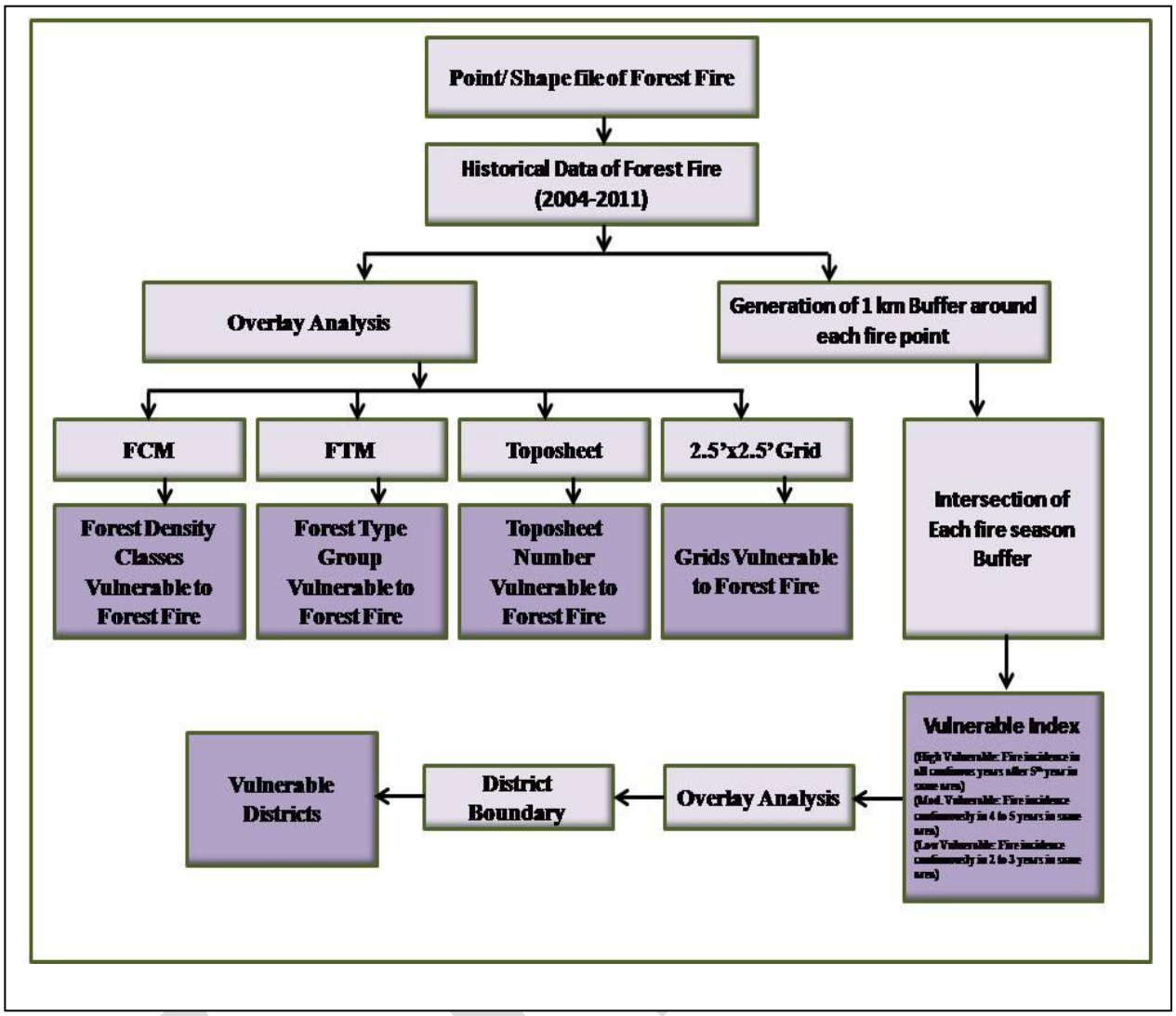

Figure 3: Methodology for the identification of vulnerable area in districts

RESULTS AND DISCUSSIONS

To find the vulnerable area, forest type, forest density class and toposheets along with the districts have been identified and analyzed. Forest fire History in Uttarakhand for all the districts are given in Table:1.

Table: 1. History of Forest fire incidences from 2004 to 2011.

District	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11
Almora	8	7	6	30	35	46	3
Bageshwar	5	0	1	16	17	31	8
Chamoli	3	5	16	36	81	22	5
Champawat	4	8	3	69	6	24	4
Dehra Dun	14	13	29	6	24	111	3
Haridwar	1	10	25	32	125	57	0
Naini Tal	22	63	21	156	9	188	16

District	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11
Pauri Garhwal	49	20	57	296	74	258	7
Pithoragarh	7	4	1	9	11	18	9
Rudraprayag	0	0	1	1	1	5	0
Tehri Garhwal	13	13	42	43	159	36	5
Udham Singh Nagar	15	20	16	20	20	29	15
Uttarkashi	2	2	4	3	69	30	10
Total	**143**	**165**	**222**	**717**	**631**	**855**	**85**

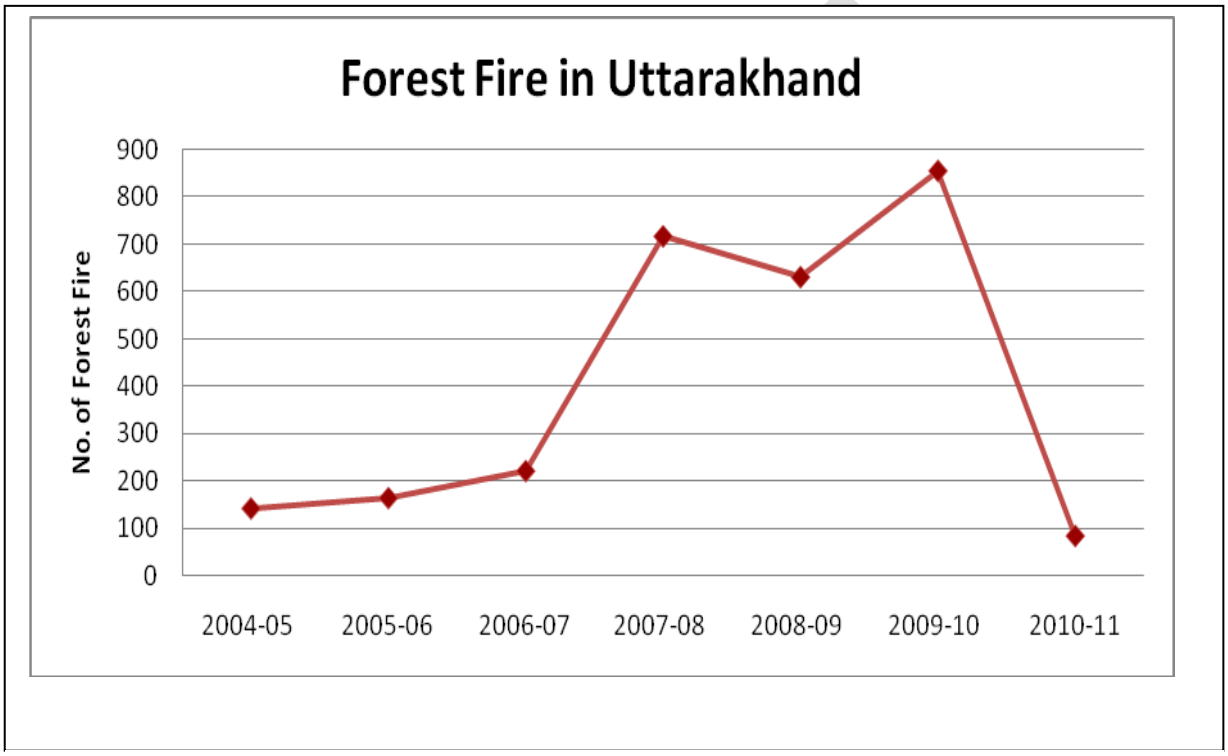

Figure 4: Trend of Forest Fires in state of Uttarakhand for different fire seasons

meteorological data. There can be a scope to find out the reason for such a kind of variations. Highest fire incidences in past seven year has been reported in Pauri Garhwal followed by Nainital and Tehri Garhwal. Rudraprayag has been reported with least forest fire incidences with an average of 1 fire incidence per year. Maximum forest fire incidences has been reported in Haridwar during 2008-09 where as for Dehradun 2009-10 was the worst year with respect to forest fires. Highest fire incidences has been reported in 2007-8 in Pauri Garhwal.

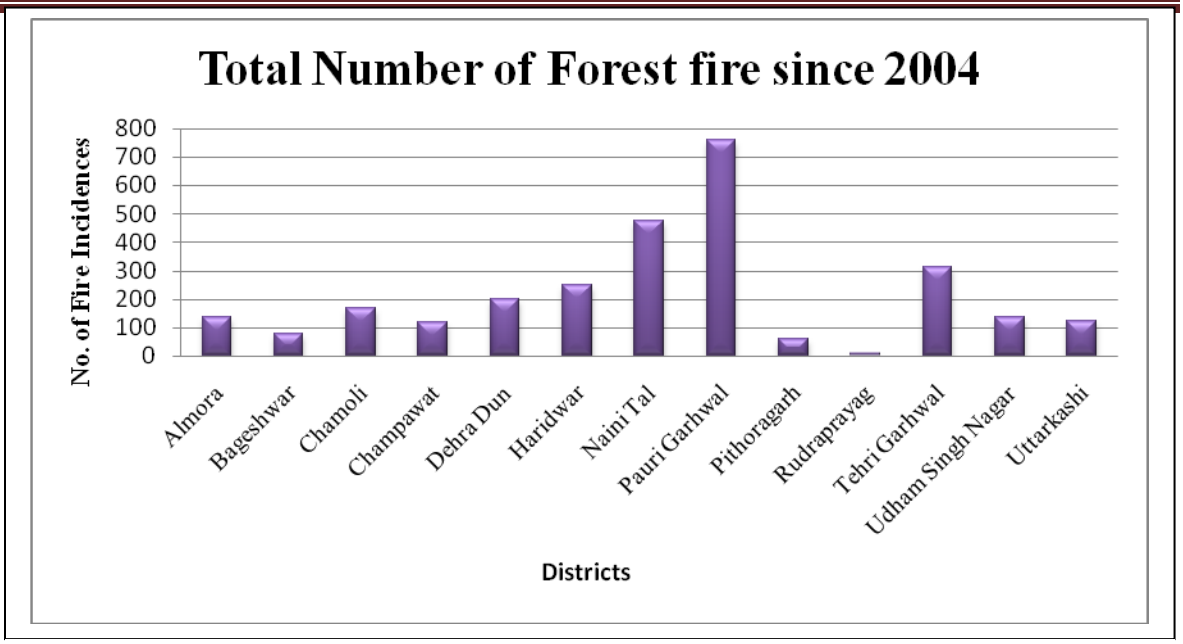

Figure 5: District wise number of forest fire incidences Uttarakhand since 2004

It has been observed during analysis that within 3 years maximum forest fire occurrence has been found in the same areas. Whereas in continuous 4 years fire incidences at the same areas have been reported in 2005 to 2009 and 2006 to 2010 as well as in 2007 to 2011, no fire incidences have been reported in the same area during 2004 to 2008. In five years continuous fire has been reported only during 2006 to 2011 whereas no fire incidences in the same area have been found during 2004 to 2009 and 2005 to 2010. There are no places where there are continuous fires incidences have been reported in continuous 6 years with in the radius of 1 km. Figure 6 shows the location of forest fire vulnerable areas in Uttarakhand state.

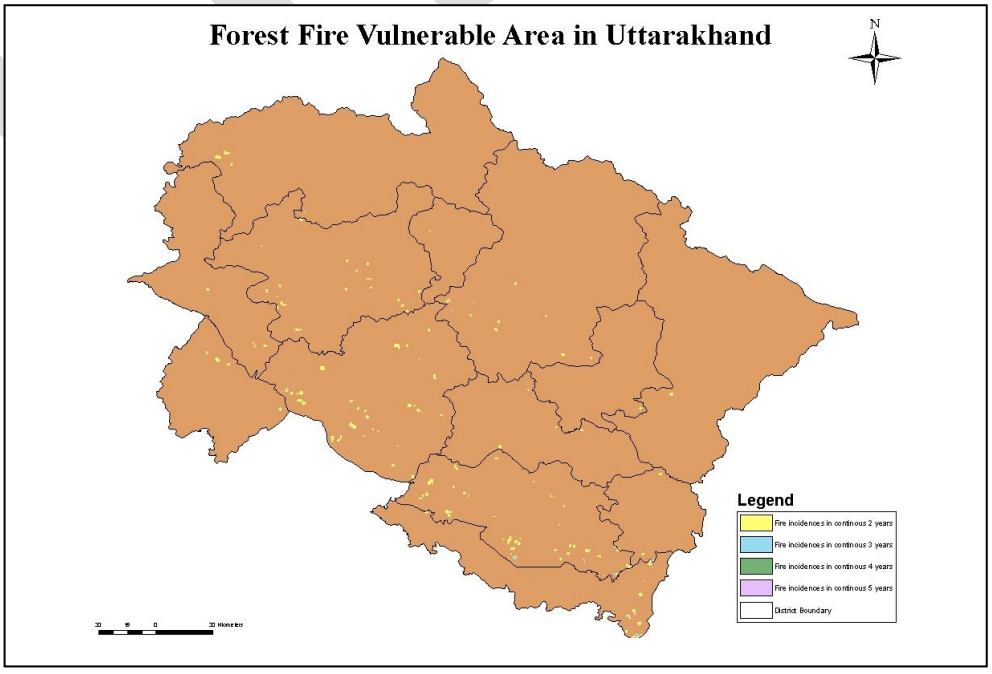

Figure 6: Forest Fire vulnerable areas in Uttarakhand

The vulnerable area is then overlaid with the district boundaries to identify the districts under which the vulnerable area lies. Districts having high vulnerable area are termed as high vulnerable district, moderately vulnerable and low vulnerable districts are those in which moderately vulnerable area and low vulnerable areas are found. On the basis of vulnerable areas Udham Singh Nagar is most vulnerable district in terms of forest fire vulnerability incidences where as Nainital is moderately vulnerable district. Almora Champawat, Chamoli, Dehradun, Haridwar, Pauri Garhwal, Pithoragarh, Rudraprayag, Tehri Garhwal and Uttarkashi are said to be low vulnerable districts based on the vulnerable analysis. District wise forest cover (ISFR 2011) of the state and its vulnerability is shown in Table 2

Table 2: List of vulnerable districts with forest cover as per ISFR 2011. (Area in km^2)

S.No.	Vulnerability	District	VDF	MDF	OF	Total	Scrub
1	Low Vulnerable	Almora	222	928	427	1577	10
2	Not Vulnerable	Bageshwar	194	883	304	1381	4
3	Low Vulnerable	Chamoli	427	1586	682	2695	6
4	Low Vulnerable	Champawat	336	571	274	1181	8
5	Low Vulnerable	Dehra Dun	584	695	328	1607	24
6	Low Vulnerable	Haridwar	26	353	240	619	0
7	Moderate Vulnerable	Naini Tal	601	1923	566	3090	13
8	Low Vulnerable	Pauri Garhwal	523	2094	672	3289	59
9	Low Vulnerable	Pithoragarh	567	1115	412	2094	32
10	Low Vulnerable	Rudraprayag	246	581	298	1125	5
11	Low Vulnerable	Tehri Garhwal	298	1232	617	2147	89
12	High Vulnerable	Udham Singh Nagar	171	247	128	546	0
13	Low Vulnerable	Uttarkashi	567	1959	619	3145	21

Table 2 shows the forest cover of the highly vulnerable district is 546 km^2 where as moderately vulnerable district is having 3090 km^2 forest which is third highest cover of the state. Though Pauri Garhwal disrrict have the highest forest cover yet it is low vulnerable district with respect to forest fire occurrences in the same area. Reason for the vulnerability may be many. But the most likely reason may be the frequent visits of the people residing in the periphery of the forest areas for firewood, fodder, and collection of minor forest produce (MFP), forest type, fuel, biotic pressure, Climatic conditions such as rainfall and temperature also influence the vulnerability of the forest fire.

An overlay analysis has been done using forest cover of the country with forest fire incidences since 2004 to find the vulnerable forest density classes. Detailed statistics has been given year wise for all the forest cover densities to find the vulnerable forest density class in Table 3.

Table 3: No. of forest fire incidences in each Forest Density since 2004

Forest Density	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	Total
Very Dense Forest	45	25	49	129	110	158	12	528
Moderately Dense Forest	66	82	116	373	314	486	40	1477

Forest Density	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	Total
Open Forest	16	43	41	161	148	152	25	586
Scrub	0	0	1	2	0	0	0	3
Non Forest	16	15	15	52	59	59	8	224
Total	143	165	222	717	631	855	85	2818

Table 3 shows that total number of forest fire incidences are more in moderately dense forest followed by open forest and very dense forest. Around 52% of total forest fire incidences have been reported in moderately dense forests where as 21% forest fire incidences have been reported in open forests and 19% forest fire incidences are in very dense forest.

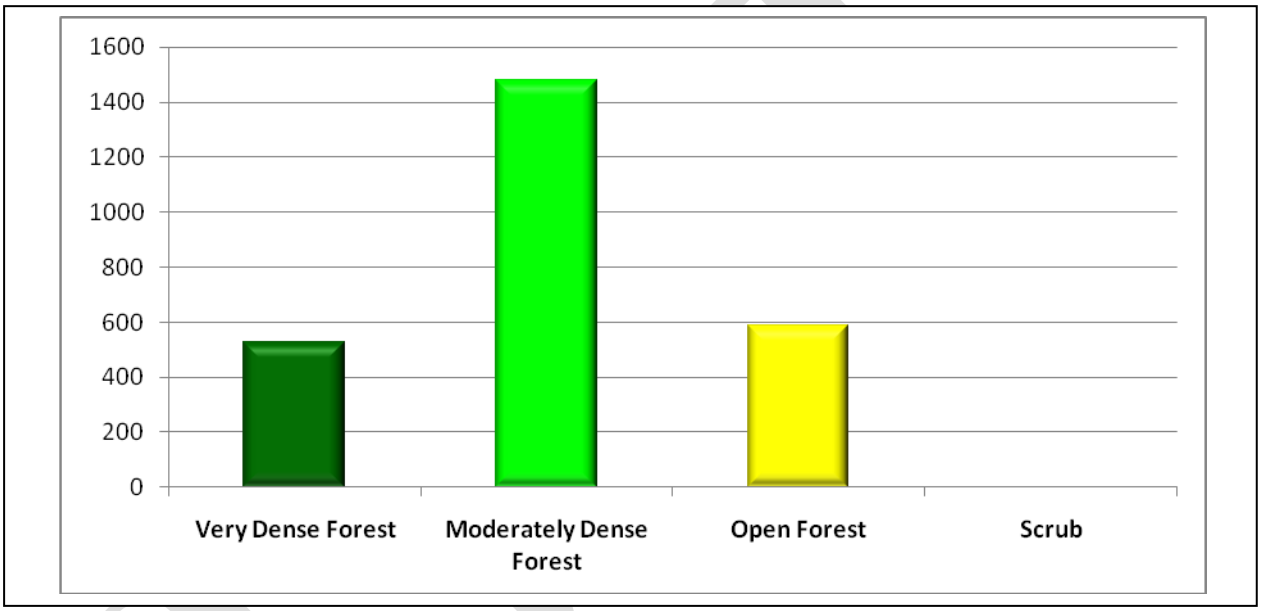

Figure 8: Forest Fire incidences in different canopy densities of Uttarakhand since 2004

The study in the past have revealed that high resin content in sub-tropical pine region and dry conditions in the tropical region have been a major cause of fire spread in India (Chandra, 2005). Therefore an analysis has been done with forest type group to find the vulnerable forest type group in the state. Table 4 shows the forest fire incidences in the forest types found in Uttarakhand state.

Table 4 Forest Type Vulnerable to forest fire

S.No	Type Group	No of fire in						
		2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11
1	Group 3 Tropical Moist Deciduous Forests	72	95	103	321	79	424	21
2	Group 5 Tropical Dry Deciduous Forests	1	10	27	72	33	99	6
3	Group 9 Subtropical Pine Forests	21	11	28	166	180	133	35

S.No	Type Group	No of fire in						
		2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11
4	Group 12 Himalayan Moist Temperate Forests	23	12	31	61	240	90	7
5	Group 13 Himalayan Dry Temperate Forests	0	0	0	0	7	0	0
6	Group 14 Sub-alpine Forests	0	0	0	0	7	6	0
7	Group 15 Moist Alpine Scrub	0	0	0	0	1	0	0
8	Plantation/TOF	3	14	12	29	12	36	5
9	Non Forests	23	23	21	68	72	67	11
	Total	**143**	**165**	**222**	**717**	**631**	**855**	**85**

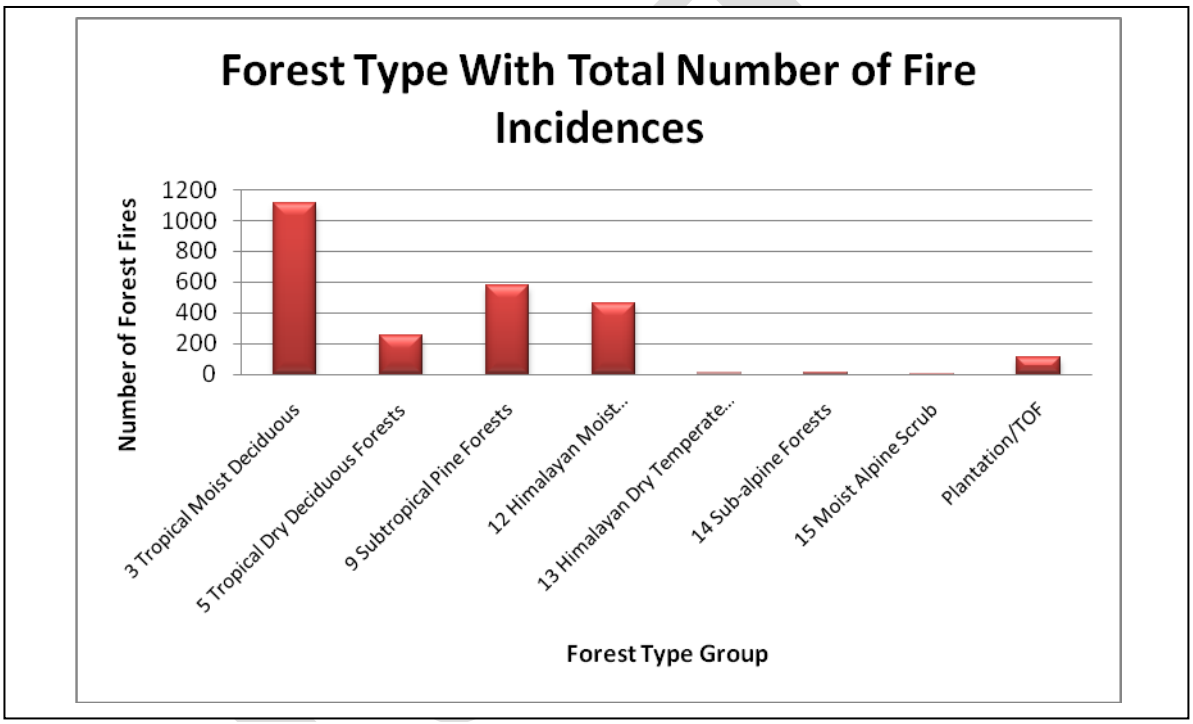

Figure 9: Forest Fire incidences in different forest type groups of Uttarakhand since 2004

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